

Geomatic Approach and Geophysical Interpretation of the Hydrogeological Basin of the Hassi Naga Region (Algerian Southwest)

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Abstract—In this work, we propose a model of Geomatics in the Hassi Naga region, which is located in the Hamada of Tindouf, southwestern Algeria, about 70 km to the northwest of the region. This approach is based on prospecting and thematic analysis of the distribution of Geoelectrical measurements in order to better estimate and manage the Hydrogeology of this region of the Tindouf basin. The results of the geophysical survey allow us to design a complete model that meets the needs of Hydrogeology, whose methodology we have applied consists of decomposing our subject into three classes of entities: Geomatic, geophysical and hydrogeological, discovering the relational links, doing the thematic analysis and ending with results that help to solve the problem of water (Hydrogeology) of the area studied.

Keywords— *Geomatic, Geoelectrical, Geophysics, hydrogeology.*

I. INTRODUCTION

The area of Hassi Naga belongs to the northern flank of the Tindouf basin, a vast asymmetric Syncline made up of a set of sedimentary formations of Palaeozoic age unconformably covered by continental deposits of the Neogene [1]. This study shows the interest of Geomatics for geoelectrical exploitation in the Hassi Naga region and facilitates spatial interpretation. The result of this research is the establishment of a Geospatial model allowing the impact of the measurements in Hydrogeology of the Hassi Naga zone [1,2]. The geophysical results make it possible to confirm that there are formations that are likely to be aquifers, and have a hydrogeological interest at the level of the Neogene complex, which brings out three classes:

- A shallow class of thickness does not exceed 140 m.
- A middle class (800 m), corresponding to the silty clays of the Upper Carboniferous.
- A class that concerns a very resistant, dry and deep substratum (≥ 800 m).

Geomatics enabled us to carry out a synthesis mapping, allowing a simulation of the position of the drill holes of

the zone of Hassi Naga. The main objective of this study is the analysis of electrical resistivity for the recognition of groundwater resources in the Hassi Naga area, located in the northwest of the Tindouf (SW - Algerian) basin. Taking into account all the existing studies and the confrontation with the results of geophysics by prospecting based on the electrical method. By measuring the resistivity of the layers, from which the lithology and the structure of the region are determined to define the aquifer levels, their geometry and their thickness. In the field of mapping and cognitive mapping, the geomatics techniques are important for the study of the surface of the earth [3]. The data are essential to any surveillance, photographic analysis and morphological modeling, whatever the scale. The new solutions are attractive, fast, usable in any type of morphological configuration and provide easily integrable data in geographic information systems, at resolutions ranging from ten meters to centimeters [4,5].

In several fields of interest in cognitive geomatics plays a central and an inescapable role on:

- Spatial uncertainty;
- Implementation of Geomatics within organizations;
- Dissemination;
- Viewing and navigating.

Geomatic parameters for geology and Geotechnics are used in geophysical measurements [6], Hamouda M and al. [7] in order to implement cognition in Hydrogeology. In this work, emphasis is placed on the contribution of topography, Photogrammetry and GIS [8,9,10], to develop thematic maps and synthesis maps. Geographical location of the study area is defined in Figure 1.

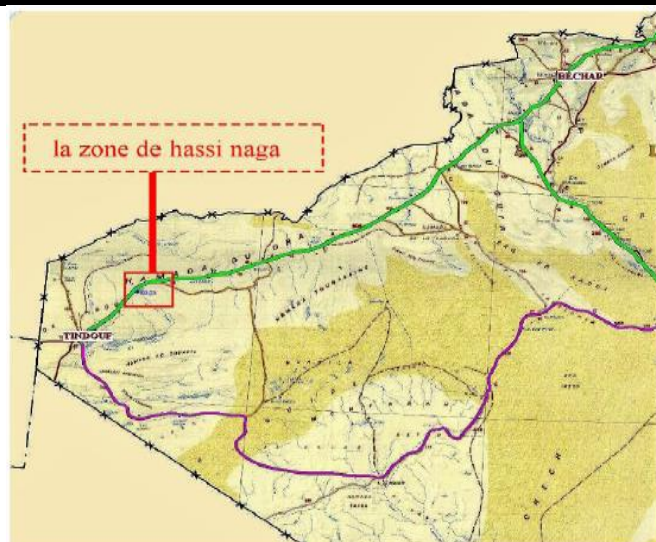


Fig. 1: Geographical location of the study area (ANRH (2015))

II. METHOD

The method of vertical electric soundings involves injecting a continuous electrical current into the ground using two stainless steel electrodes and measuring the potential difference created between the terminals of two other copper electrodes [11,12,13]. The assembly constitutes a quadrupole as it is in the following figure, a resistivity meter is used to measure the electrical current and the potential difference; and allows us to determine the apparent resistivity of the medium according to the scheme and the following formulas [14,15]:

There are several devices of the models of quadrupoles; the most used are those of Wenner and Schlumberger.

- The Wenner: all the electrodes are equidistant, $AM = MN = NB = AB / 3$

- The Schlumberger: The distance MN is small compared to AB . In general $MN < AB / 5$

2.1. Mathematical model

The electrical method involves injecting a continuous electrical current into the ground using two stainless steel electrodes and measuring the potential difference created between the terminals of two other copper electrodes. The assembly constitutes a quadrupole as shown in the following figure; an ammeter is used to measure the electrical current and a voltmeter to measure the potential difference (Figure.2):

The idea is to move the four (AMNB) electrodes together and thus to produce profiles and resistivity maps. The devices are numerous and varied, the quadrupole remains the most widespread. The source of current is typically 90-volt batteries, more rarely a gasoline generator with a rectifier or a car battery, the new devices walk with ten (10) batteries in series [16, 17].

This method makes it possible to measure the difference of potential ΔU and the electric current injected and recovered in the subsoil I, it remains for us to calculate the resistivity ρ in the one medium considered with two poles A and B, the action conjugate of A and B will give [18]:

- Potential in M:

$$U_M = \frac{\rho I}{2\pi} \left(\frac{1}{AM} - \frac{1}{BM} \right) \quad (1)$$

- Potential in N:

$$U_N = \frac{\rho I}{2\pi} \left(\frac{1}{AN} - \frac{1}{BN} \right) \quad (2)$$

- Difference potential between M and N:

$$\Delta U = U_M - U_N = \frac{\rho I}{2\pi} \left(\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN} \right) \quad (3)$$

From where :

$$\rho = \frac{k \cdot \Delta U}{I} \quad (4)$$

With:

$$k = \pi \cdot \frac{AM \cdot AN}{MN} \quad (5)$$

- The resistivity in the medium in (ohm-meter) is calculated by:

$$\rho_a = \frac{k \cdot \Delta U}{I_{AB}} \quad (6)$$

With:

k : a geometrical factor which depends only on the relation of the electrodes and is expressed by (5);

ΔU : potential difference across the electrodes MN;

I_{AB} : intensity of the electrical current flowing in the circuit AB.

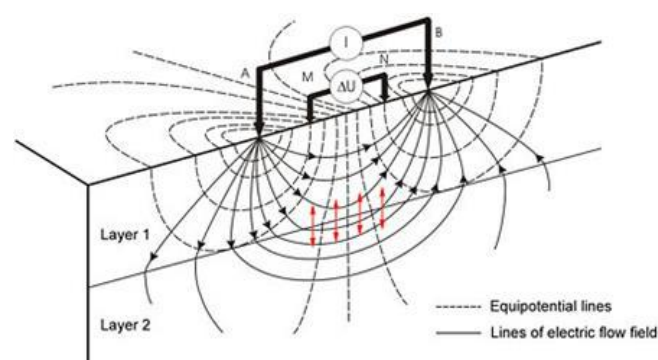


Fig. 2: Schlumberger scheme chosen for the prospecting of the present work

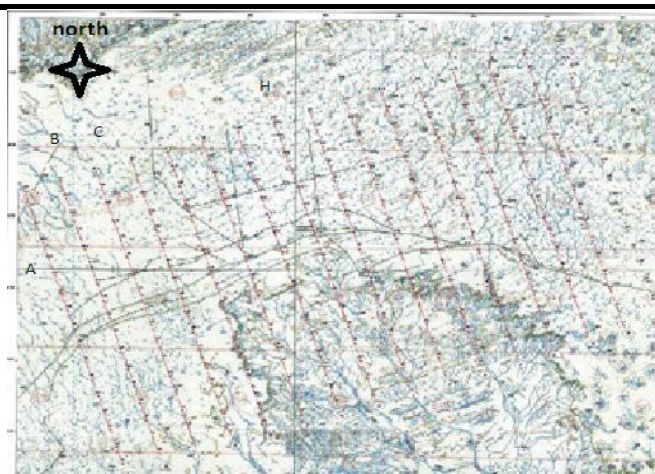


Fig. 3: Profile map (A-P) and points of the field soundings

Cuts and geophysical profiles allowed us to construct two levels of analysis by aggregation of the resistivity's, level 1 (R1, R2, R3 and R4) and level 2 (R5, R6, R7 and R8). These two levels are shown in Figure 4.

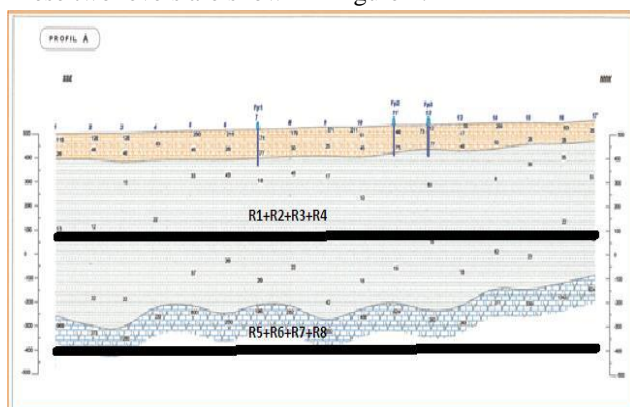


Fig. 4: Profile representing resistivity levels varying between R1 and R8

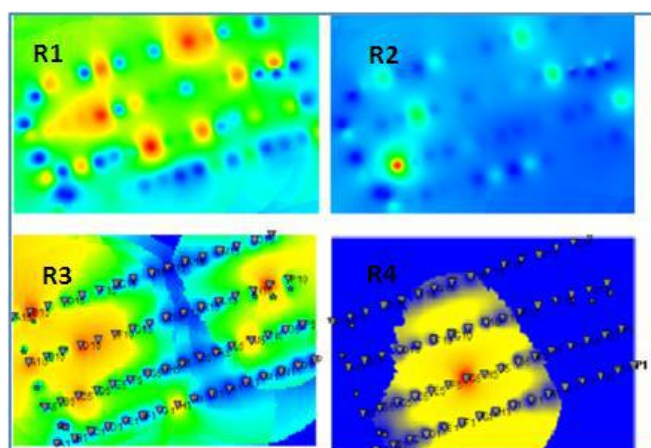


Fig. 5: Spatial distribution of resistivity, level 1 (R1, R2, R3, R4)

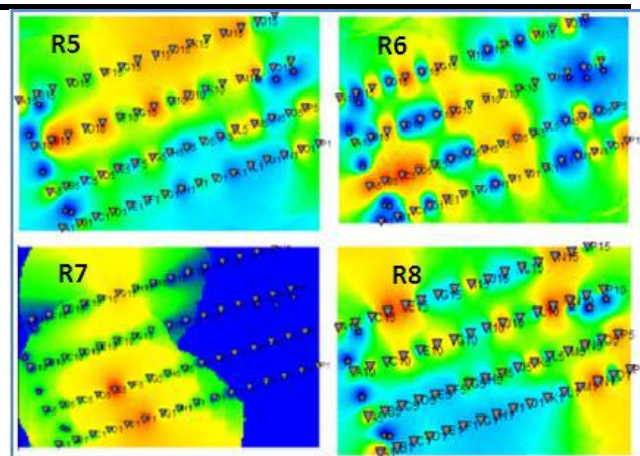


Fig. 6: Spatial distribution of the resistivity, level 2 (R5, R6, R7, R8)

III. RESULTS AND DISCUSSION

The result is based on the interpretation of the maps of apparent resistivity's:

The results of the interpretation are expressed as interpretive geoelectrical cuts and maps of apparent resistivity Figures 5 and 6. All the profiles are oriented South-South-East / North-North-West with similarities in their monotonous appearance, in the thicknesses of the formations Geological features, and by the nearly similar recorded resistivity. On the surface, the resistivity's are high, reflecting, due to the characteristics of the hard and compact limestones covering a large part of the Hamada. Geoelectric Cuts of profile A: Depending on the resistivity and the thicknesses, three classes are to be considered:

Classes #1: 120 m thick with a first resistivity range of 118 to 571 Ohm-m, relative to the limestone crust of about 1m thickness, and a second range of 25 to 77 Ohm-m corresponds to the formation Neogene of Hamada (clay, sandy clay with limestone intercalation).

Class #2: 600 to 700 m thick, with a resistivity of 8 to 62 Ohm-m. Land of the Upper Carboniferous.

Class #3: 700 to 800m, with resistivity from 196 to 1342 Ohm-m. Relative to the lower Carboniferous (Upper Viséan), their thickness is 578m.

The summary of class resistivity is defined in Table I.

3.1. Comments and discussions

- Map of apparent resistivity's (AB = 450 m)

The depth of investigation for a line AB equal to 450 m will be located at a depth of 100 to 150m, which characterizes the nature of the Neogene Hamada. The values of the apparent resistivity's are divided into two orders of magnitude:

A relatively conductive range: of which ($R_o < 60$ Ohm-m) in the majority of the electric soundings would suggest low clay levels.

A relatively high range: at the soundings of which: ($R_o > 80 \text{ Ohm-m}$), in the majority of the electric soundings would suggest low clay levels: ($R_o > 120 \text{ Ohm-m}$). Would be clayey sandy levels.

- Map of apparent resistivity's ($AB = 2000 \text{ m}$)

The depth of investigation for a line AB equal to 2000 m will be located at a depth of 300m to 400m, which characterizes the nature of the Upper Carboniferous represented by silty clays. The values of the apparent resistivity's are divided into two orders of magnitude:

Relatively conductive range: of which ($20 < R_o < 60 \text{ Ohm-m}$) throughout the map.

Range of which: ($R_o > 80 \text{ Ohm-m}$) indicates the existence of sandy levels within this clay-silty complex.

- Map of apparent resistivity's ($AB = 6000 \text{ m}$)

The depth of investigation for a line 6000 m AB corresponding to the lower Carboniferous resistant substratum (Viséen higher 1200 m to 1500 m) of dolomitic limestone type with anhydrite intercalation. The values of the apparent resistivity's are divided into two orders of magnitude:

Conductive plate of which: ($R_o < 60 \text{ Ohm-m}$) which corresponds to dolomitic limestones with a high proportion of anhydrite.

A relatively high plateau of which: ($R_o > 80 \text{ Ohm-m}$) corresponding to dolomitic limestone with very low intercalations of anhydrite.

- Top Carboniferous Roof Map

The Upper Carboniferous roof forms the Hercynian discordance which constitutes the very thick impermeable substratum of the Neogene's Hamada. In the area of Hassi Naga is escaped from all violent tectonics in general and their roof is at shallow depths (320m and 480m). The ascent of the roof gradually proceeds from South to North.

- Lower Carboniferous roof map (Upper Viséen)

We note the existence of numerous undulations due to the high resistivity's of the depths of the Upper Viséen; the values range from 450m in the south towards 100m in the north, indicating the elevation of the substratum in the northern part of the study area.

3.2. Confirmation and verification of tests

The structure and nature of the subsoil were developed and considered according to the calibration of the tests. The latter is done in accordance with the oil drilling data NG1 [6], located in the study area and the available hydrogeological information on the region. The comparison of the results with existing boreholes offers a good check and justify the continuity of the geological

formations and lithological conformity with the classes envisaged by the geophysics. The geoelectric sections of **A** to **D** show a calcareous substratum with intercalation of anhydrite resistant to very strong dry belonging to the upper Viséen, a very thick clay-silty formation, the Heterogeneous Neogene more heterogeneous changes of lateral facies important. The sections from **E** to **H** show the structure that **A** and **B**, with the following features: resistant substratum, the Upper Carboniferous is very clayey, a remarkable dip of the structures towards the South and a slight thickening of the Hamada from the Neogene to the South. The same geological pattern is observed on sections **I** and **L**, with the following two elements: a relative thinning of the upper Carboniferous clay-silty complex in the northern part of the study area. A remount of the resistant substrate towards the north. The geological sections from **M** to **P** in the eastern part of the study area show a continuity of the same geological structure observed in the previous sections with a deep resistant substratum.

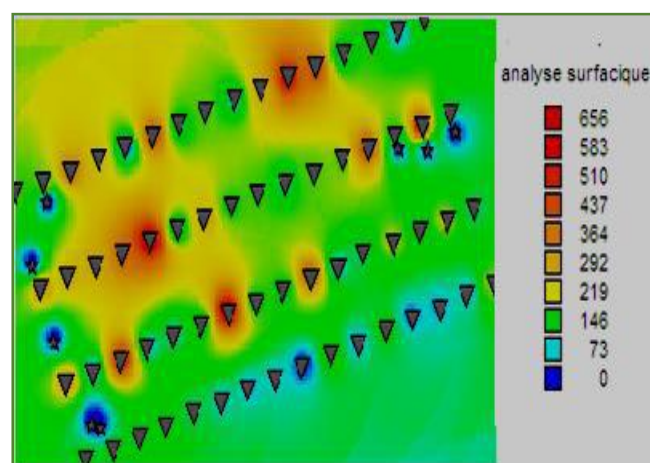
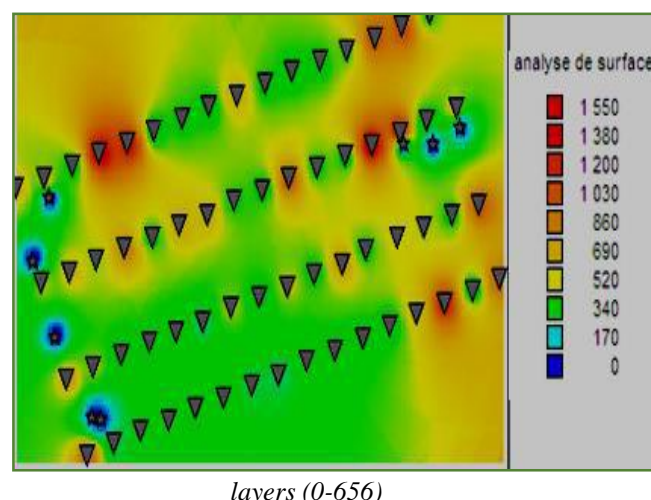


Fig. 7: Aggregation of the resistivity for R1-R4



layers (0-656)

Fig. 8: Resistivity aggregations for the R5-R8 layers (0-1550)

Figures 7 and 8 show maps using the aggregation function (sum) for two levels (N1 and N2). The zones in blue show the possibility of a positive drilling and the zones in red express a hard and deep base.

IV. CONCLUSION

This work is a contribution of geoelectrical prospecting for the needs of hydrogeology. The balance sheet is structured around a model that takes into account three classes highlighting three facies. Topography, geophysics and hydrogeology have allowed us to structure geological information. The spatial relations between these classes gave us thematic maps to locate the presence of water in the aquifer belonging to the Neogene formations and other horizons, especially in the Upper Carboniferous. The resistivity's of the latter are of the order of 90 Ohm-m and more, is likely to indicate aquifers. The spatial

mapping allowed us to delimit the zones in relation to the topographic surface and to visualize the shape of the level surface as a function of the geoelectrics data. The integration of other geophysical methods, taking into account all the geological parameters, and the geomatics data available in the region in hydrogeological matters, can help us to develop and modernize the proposed analysis model towards a good exploitation and integrated water resources management.

ACKNOWLEDGEMENTS

Our acknowledgement also goes to the managers of the Algerian water laboratory and the water resources services of the Tindouf region for the consultation of the data's.

Table.1: Summary of distribution of resistivity.

Profiles	Class 1 (C1) (Ohm-m)	Class 2 (C2) (Ohm-m)	Class 3 (C3) (Ohm-m)	Observations
B	31-116	18-52 / 70-102	190 -1342	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous
C-D	≥ 200	10 – 57	234 - 1453	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous
E-F	20 - 200	15-50 / 65-73	205 - 1216	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous..
G-H	21 - 90	11 – 41 / 52 - 57	≥ 229	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous..
I-J	≥ 129	< 100	< 50	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous
K-L	77-115	< 50	≥ 350	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous
M-N	$< 43 / 58 - 265$	$< 50 / \geq 400$	≥ 350	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous
O-P	$< 30 / \geq 45$	10 - 46	≥ 200	C1: Neogene of the Hamada C2: Carboniferous Superior C3 : Lower Carboniferous

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